Large-Angle Optimal Low-Thrust Transfer of GEO Satellites Applying a Quaternion-Based Formulation

Paola Libraro,[1] and N. Jeremy Kasdin[2]
[1,2]Department of Mechanical and Aerospace Engineering, Princeton University,
Olden Street, Princeton, NJ, 08544, USA
ph: 609-258-5673, fax: 609-258-6109
plibraro@princeton.edu

The transfer of telecommunication satellites to Geostationary Earth Orbit (GEO) can significantly benefit from the use of Electric Propulsion (EP). More room for payload and less expensive launch vehicles would re-define the GEO mission scenario if electric thrusters were used to perform primary maneuvers. Although a low-thrust transfer to GEO can be performed starting by any injection orbit, high-inclination orbits are of great interest for two main reasons. First, considering the eight-like shape of the Van Allen radiation belt around the Earth, starting the transfer from a high inclination allows a reduction of the time spent by the satellite in the most hazardous regions for the silicon cells of the spacecraft solar arrays. Second, a high-inclination orbit implies a shorter coasting time or battery usage because of the reduction in encounters of the satellite with the Earth's shadow. The final goal of our study is to fully investigate the potential of high-inclination orbit options for all-electric telecommunication satellites. We first developed a globally nonsingular quaternion-based formulation of the equations of motion of the spacecraft (*1*). This is necessary in order to perform a large angle maneuver to GEO without incurring any singularity. The next step after introducing a new set of dynamics equations was to include them into the optimal low-thrust problem and optimize co-planar transfer scenarios (*2*) both on the polar and equatorial planes. The focus of the present work is to consider plane-change maneuvers and optimize when large-angle transfers are considered. We start from the low-thrust minimum-time problem optimized using a direct optimization scheme. The results of the optimization in the case of high-inclination injection orbit scenarios are presented here along with important considerations about transfer time and electric propulsion devices to be used in such scenarios. Moving forward with our work, we plan on including radiation as well as perturbative forces in the dynamical model in order to produce a comprehensive analysis of the optimal low-thrust problem.

References

1. Paola Libraro, N. Jeremy Kasdin, Edgar Y. Choueiri, and Atri Dutta, "Quaternion-Based Coordinates for Nonsingular Modeling of High-Inclination Orbital Transfer", Journal of Guidance, Control, and Dynamics, Vol. 37, No. 5 (2014), pp. 1638-1644, doi: 10.2514/1.G000613.

2. Paola Libraro, N. Jeremy Kasdin, Atri Dutta, and Edgar Y. Choueiri, "Application of a Quaternion-Based Formulation to the Electric Orbit-Raising of GEO Satellites from High-Inclination Injection Orbits", AIAA/AAS Astrodynamics Specialist Conference, San Diego, CA, 4-7 August 2014.